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science for a changing world

SCRIPPS INSTITUTION OF OCEANOGRAPHY

The growing range of climate change impacts in California & the West

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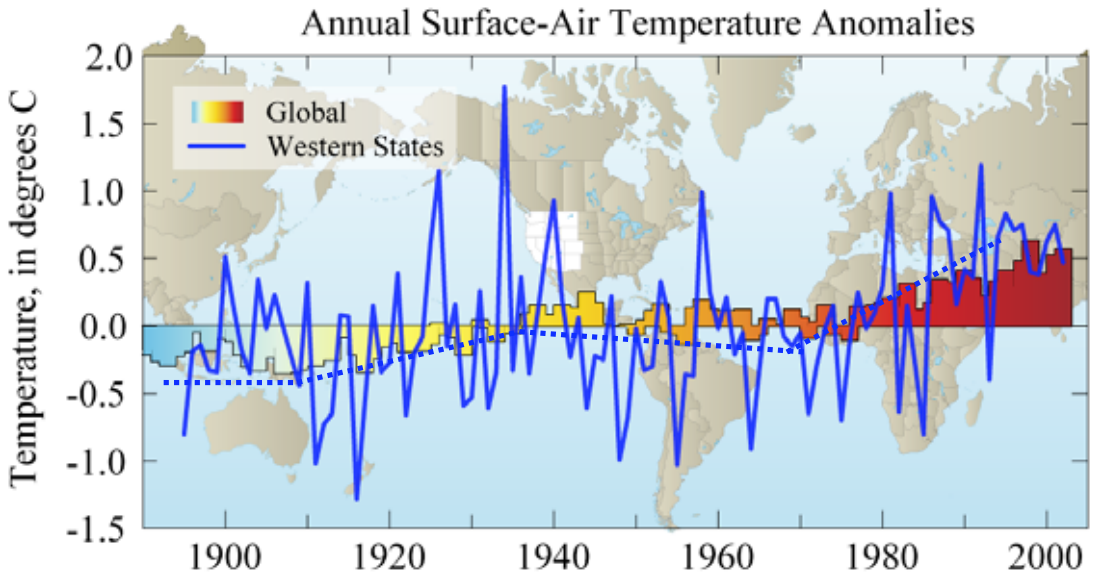
NOAA OGP's California Applications Program

Recent trends:

The western states have been warming in recent decades.



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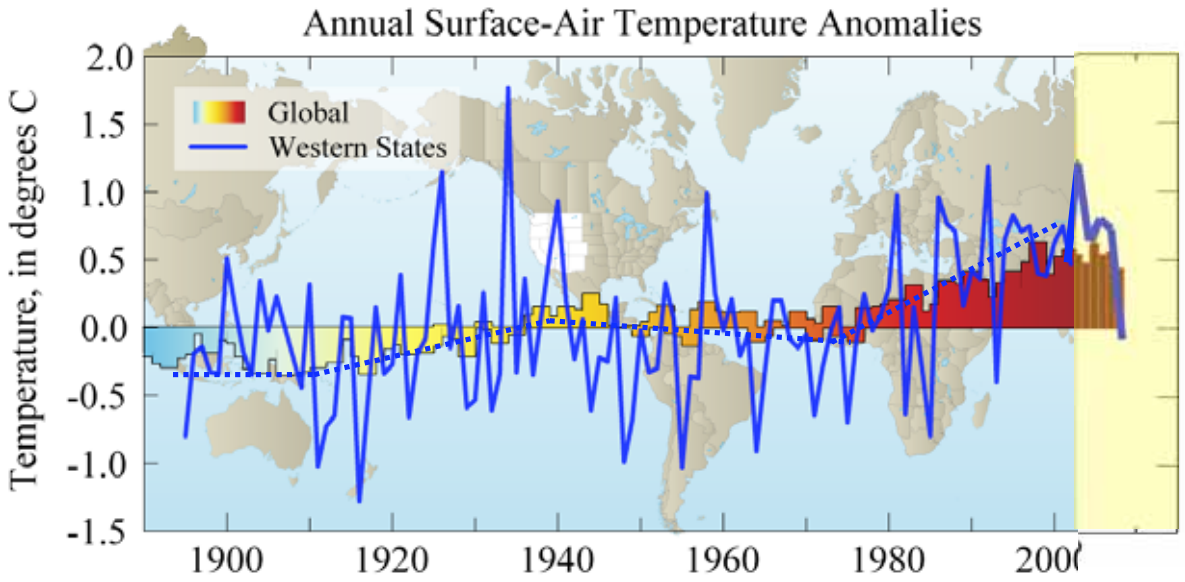
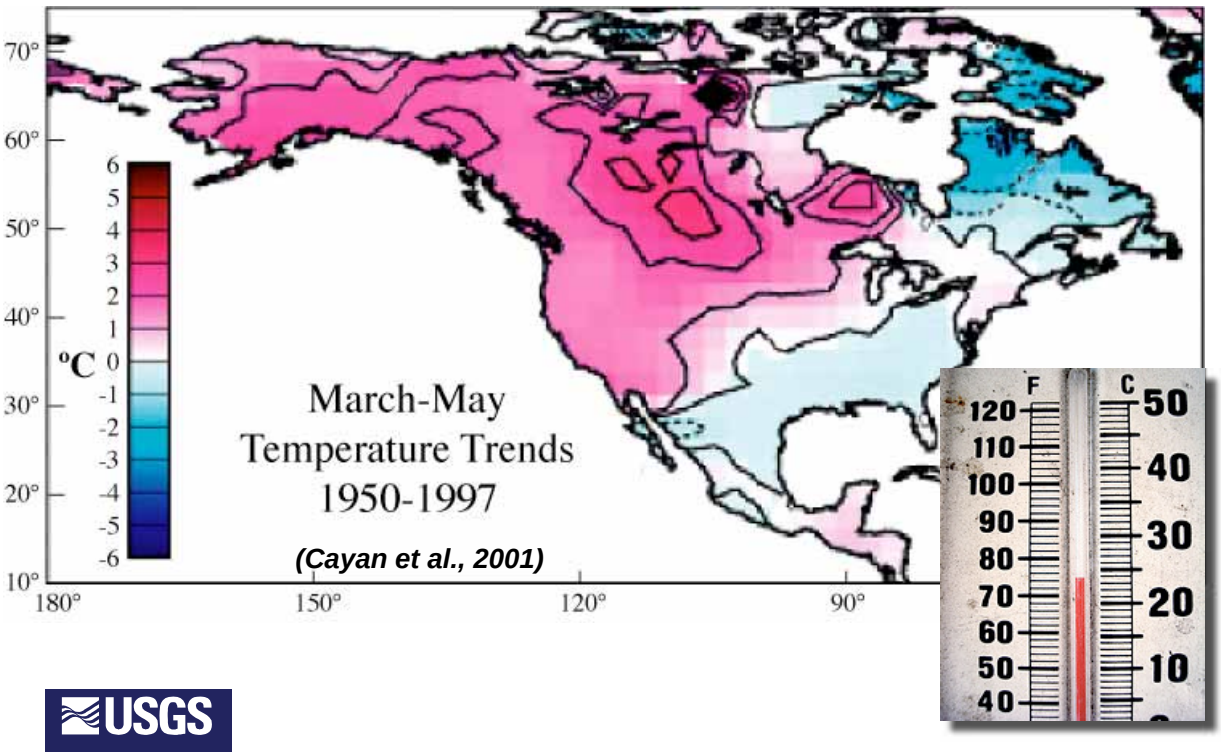
More-recent trends:

The western states have been warming in recent decades, and has continued extreme warmth in past decade.



Recent trends:

Geographically, here is the pattern of warming.



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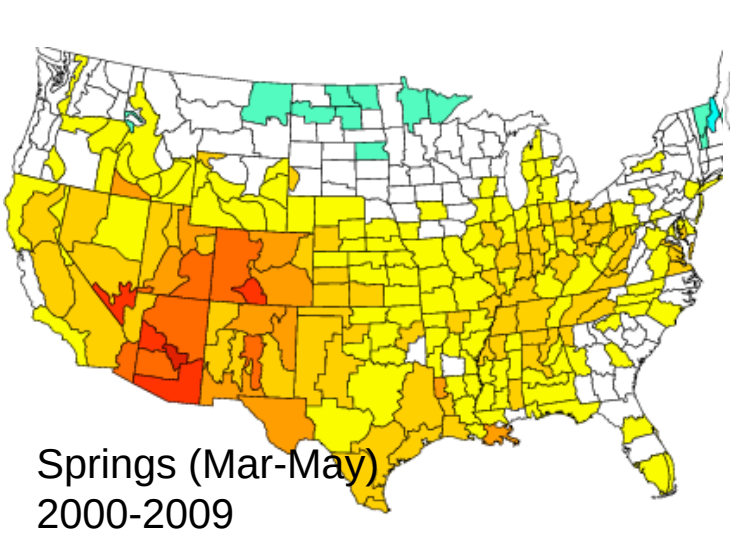
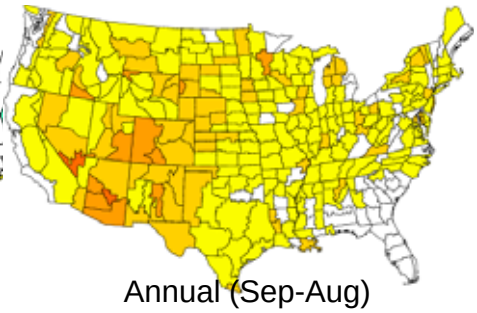
Here is the pattern of warming since 2000.

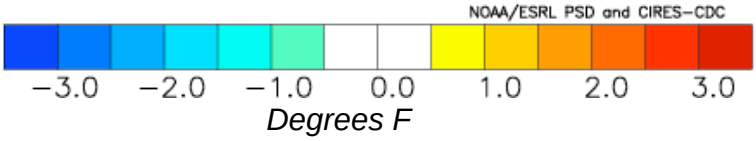
Deviation from 1971-2000 average temperatures:

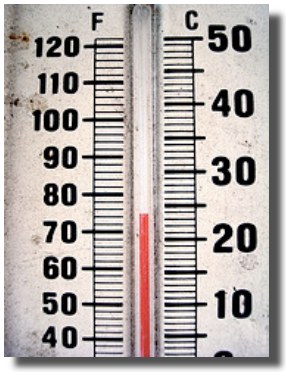


Springs (Mar-May)
2000-2009



Annual (Sep-Aug)
2000-2009

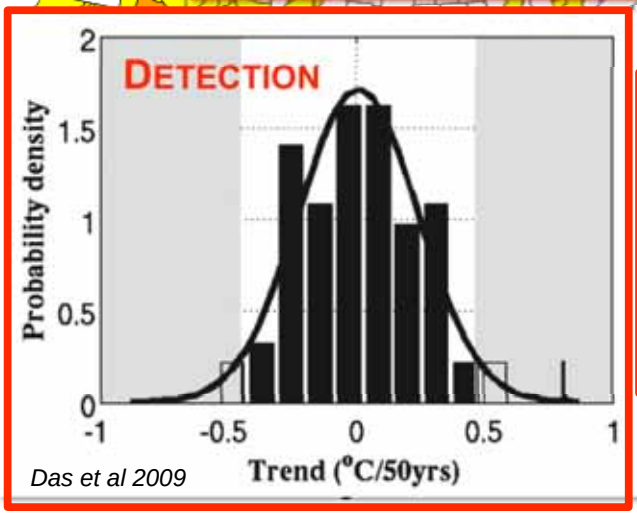


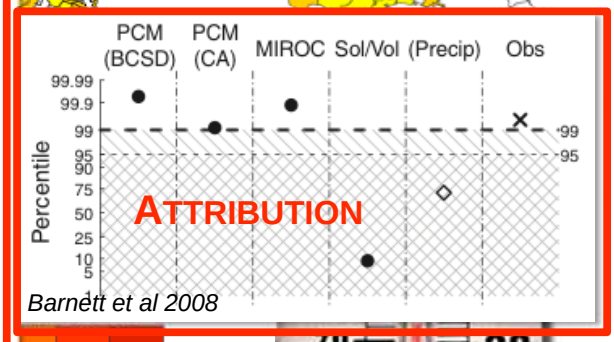


Here is the pattern of warming since 2000.

De

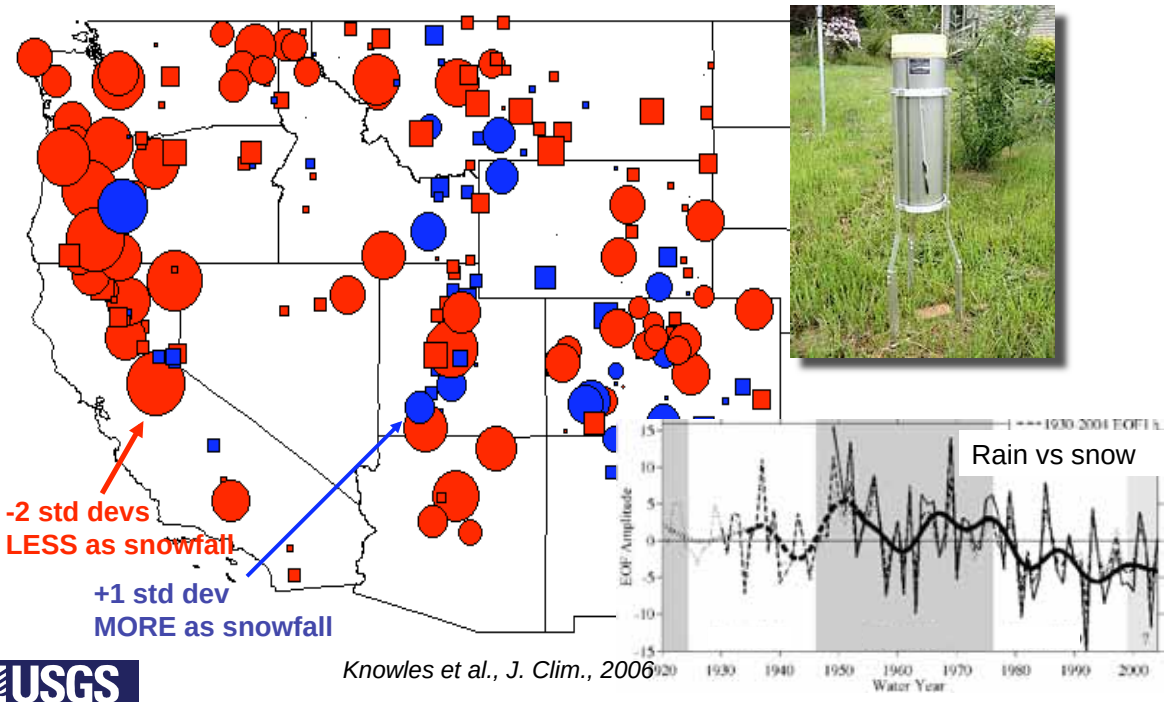
Bonfils et al., J. Clim., 2008 → Formal attribution of 1950-99 western winter Tmin changes to greenhouse origins!





Recent trends: This warming has already driven measurable hydrologic changes.

--> Less snow/more rain



Knowles et al., J. Clim., 2006

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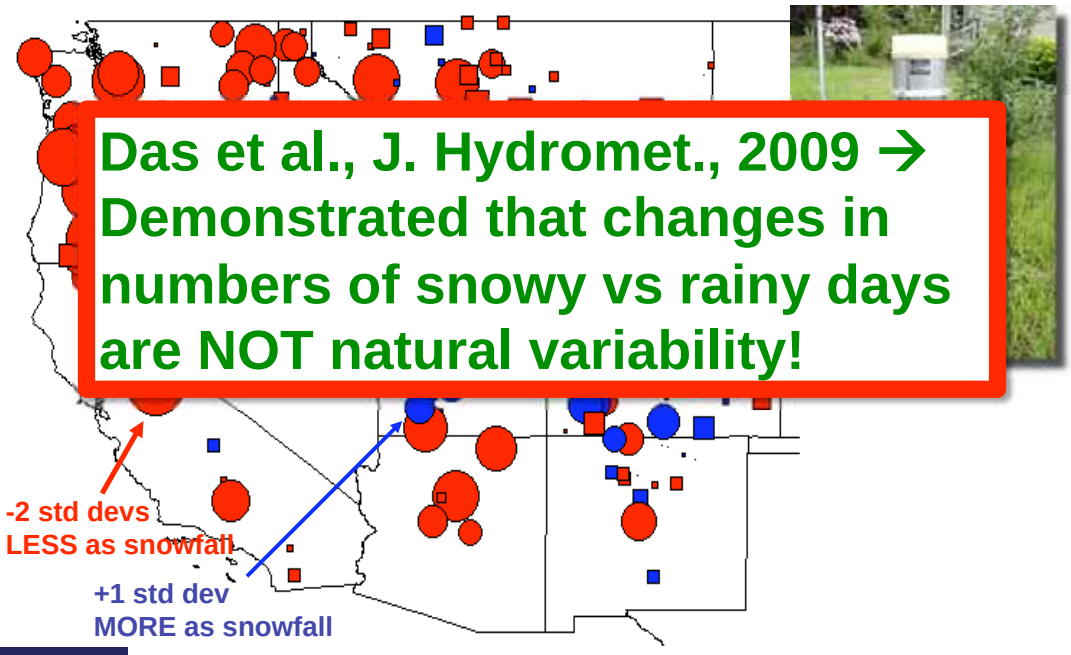

Das et al., J. Hydromet., 2009 → Demonstrated that changes in numbers of snowy vs rainy days are NOT natural variability!

Knowles et al., J. Clim., 2006

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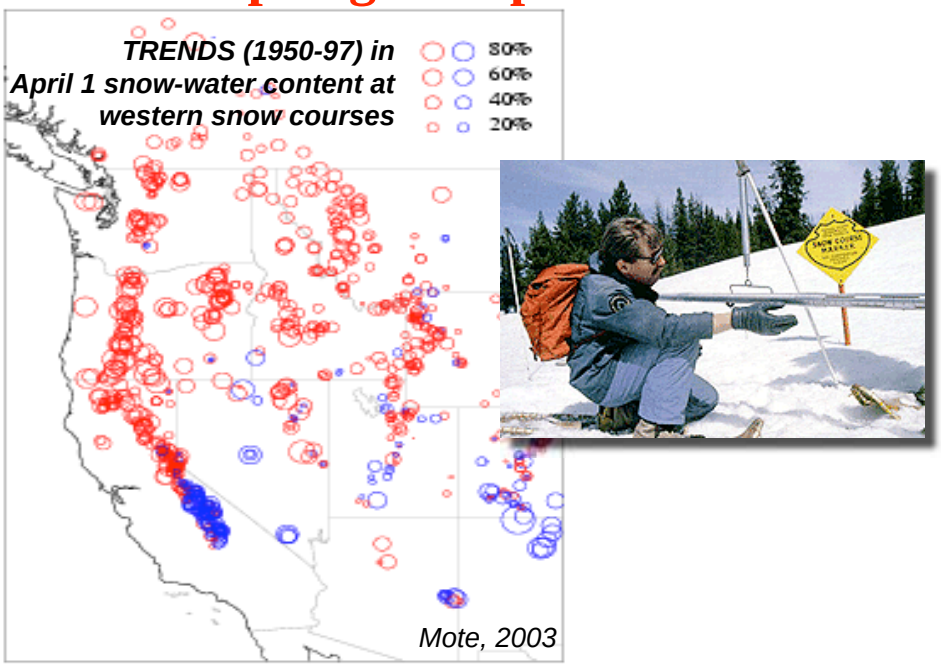
Recent trends:

This warming has already driven measurable hydrologic changes.

--> Less spring snowpack



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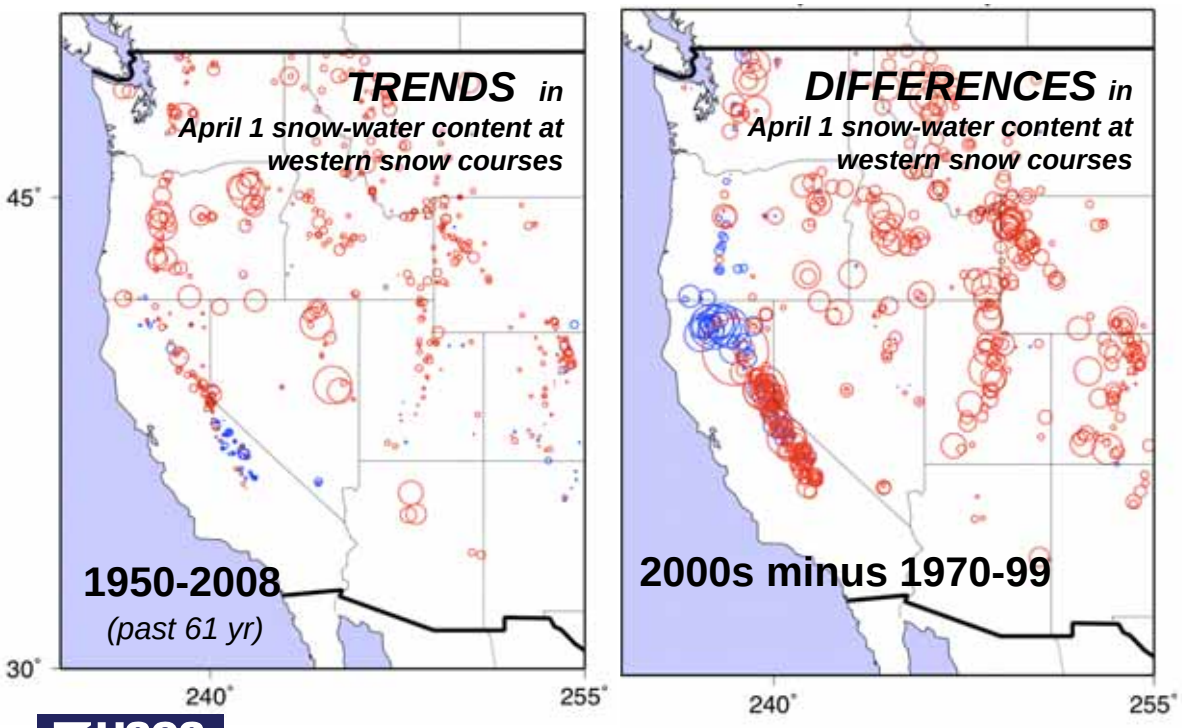
More recent trends:

--> Snowpack declines continue



USGS

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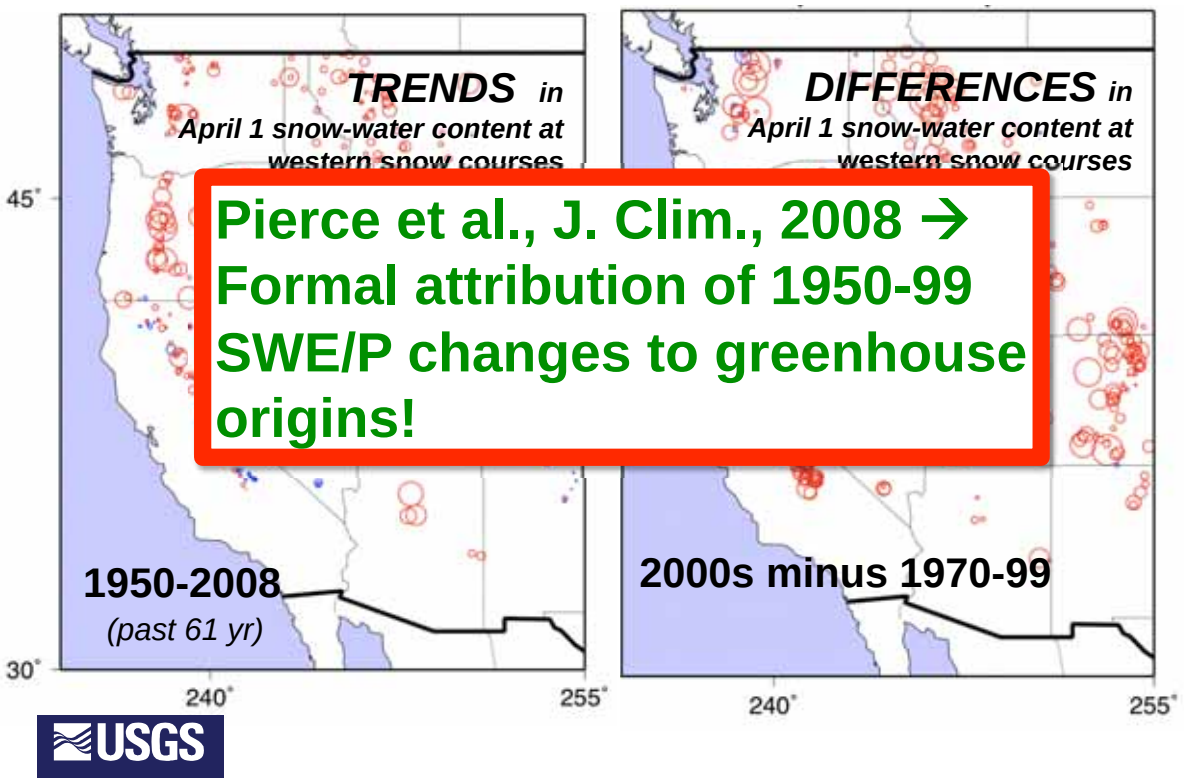

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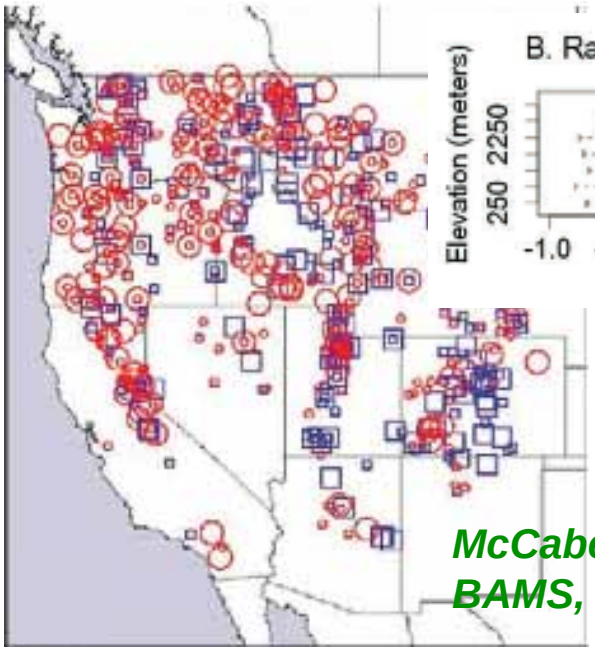
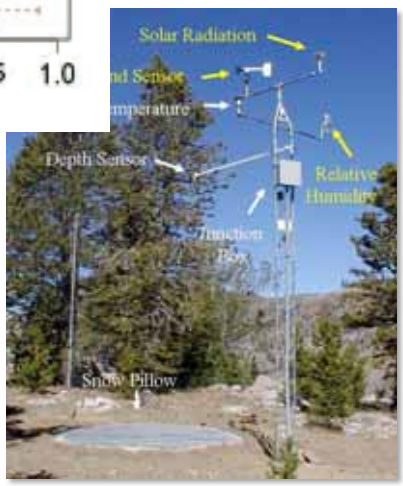
OTHER recent trends:

→Less rain-on-snow at low altitudes;
→More rain-on-snow at high altitudes



McCabe et al., BAMS, 2006



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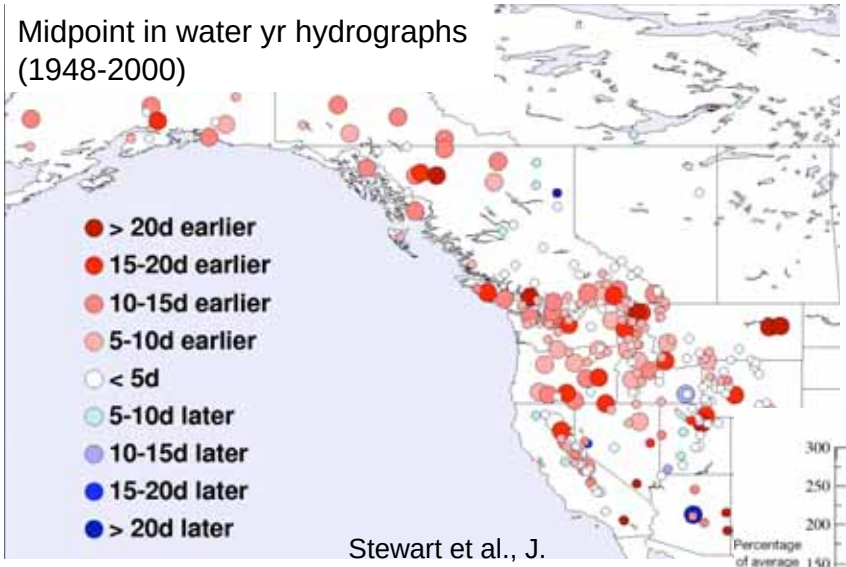
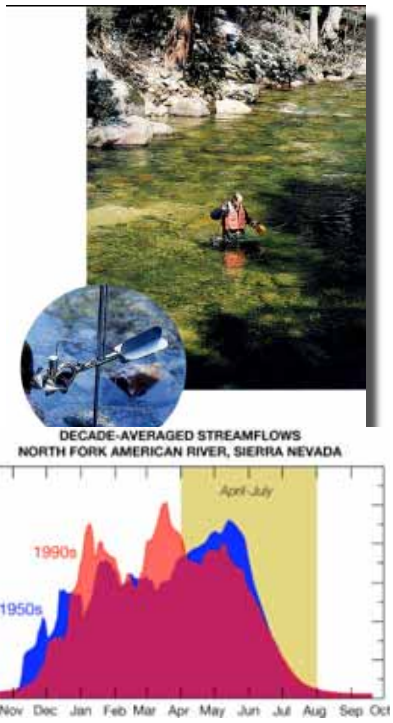
Recent trends:

--> Earlier snowfed streamflow



Stewart et al., J. Clim., 2005



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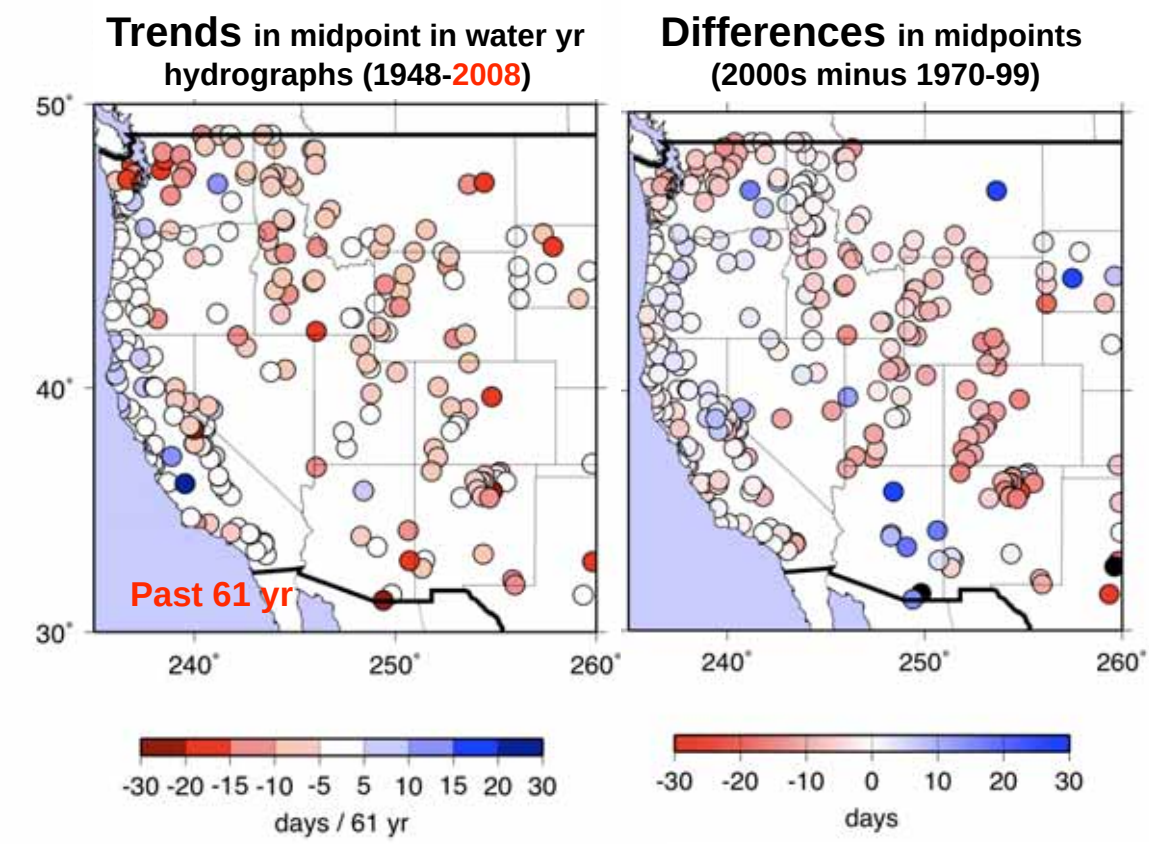
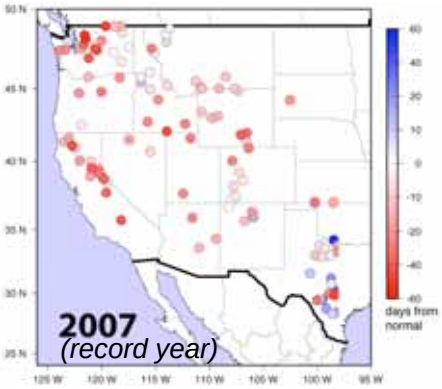
--> Earlier snowfed streamflows continue

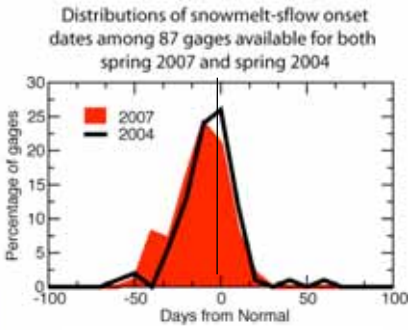


--> Earlier snowfed streamflow recordholders



Two record-breakingly early spring runoff seasons in the past 10 yr!

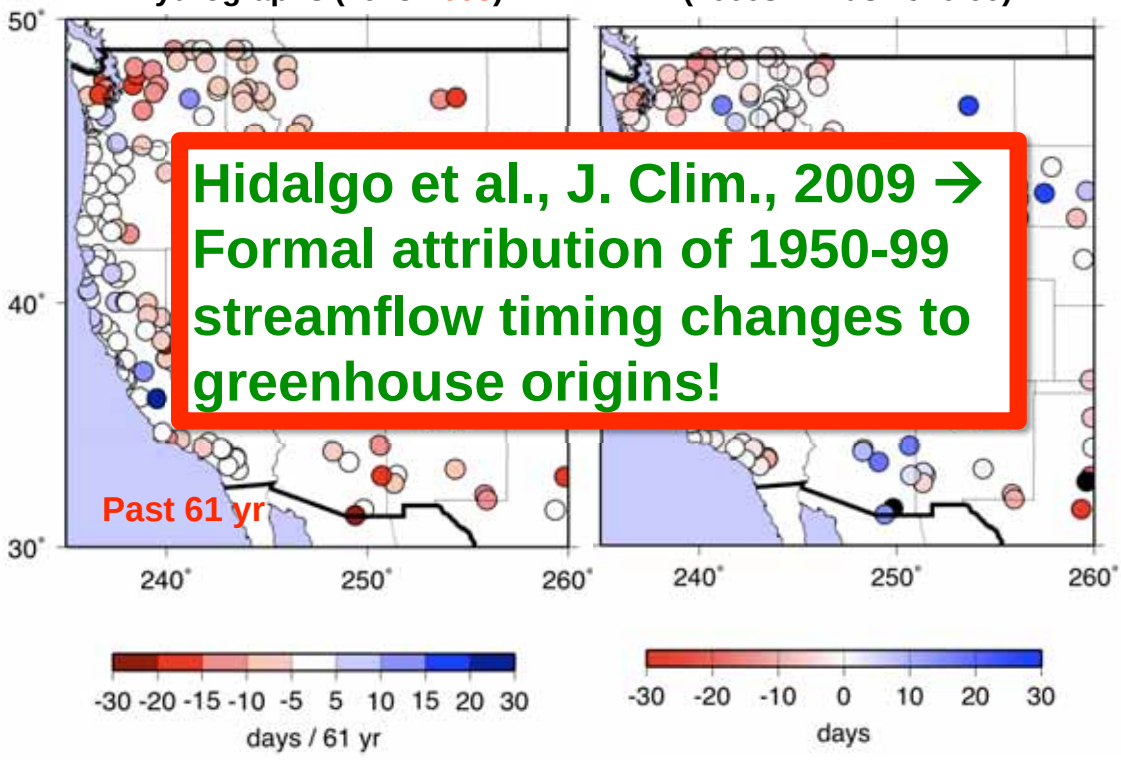
(Most gages with earlier runoff in past 50 yrs)



--> Earlier snowfed streamflows continue

Trends in midpoint in water yr hydrographs (1948-2008)

Differences in midpoints (2000s minus 1970-99)



Hidalgo et al., J. Clim., 2009 → Formal attribution of 1950-99 streamflow timing changes to greenhouse origins!

TRENDS IN CENTER OF FLOW DATES

TRENDS in April 1 snow-water
nt at snow courses

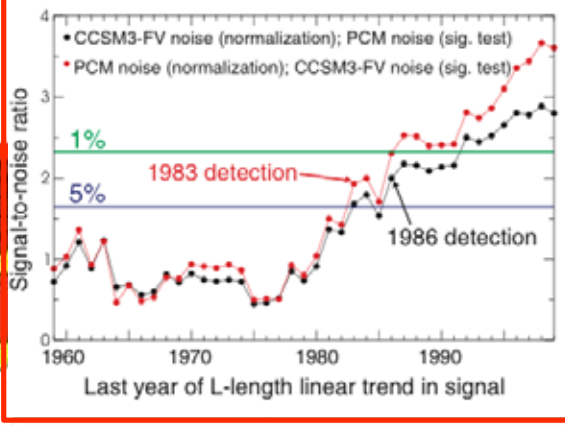
Barnett et al., Science, 2008 →
Formal detection & attribution of the combination of changes in

- **winter temperature**
- **SWE/P**
- **streamflow timing**

to greenhouse origins!

-30 -20 -15 -

When did detection become possible?



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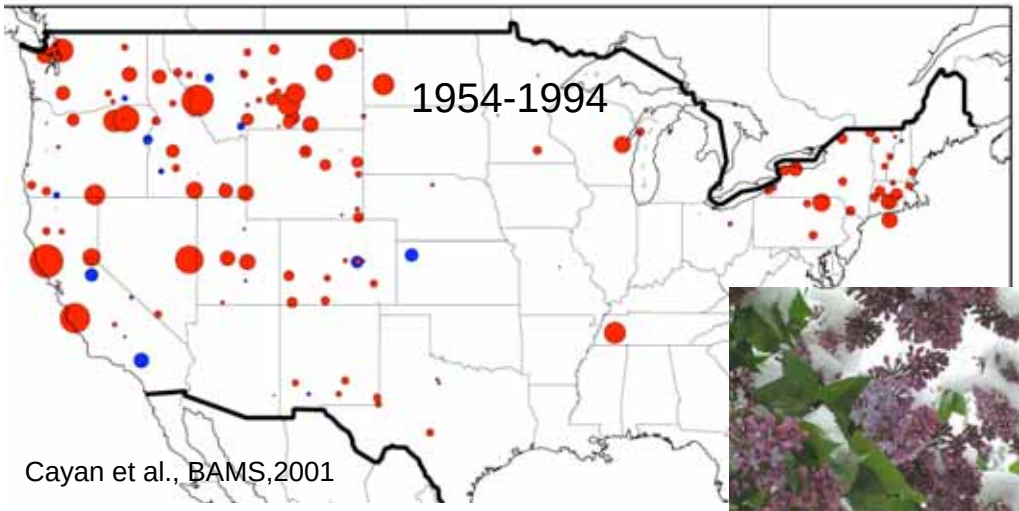
Recent trends:

This warming has extended growing seasons.

--> Earlier blooms & greenup dates

DOTS: TRENDS IN LILAC FIRST-BLOOM DATES (Sites with 20+yrs of record)



Cayan et al., BAMS,2001

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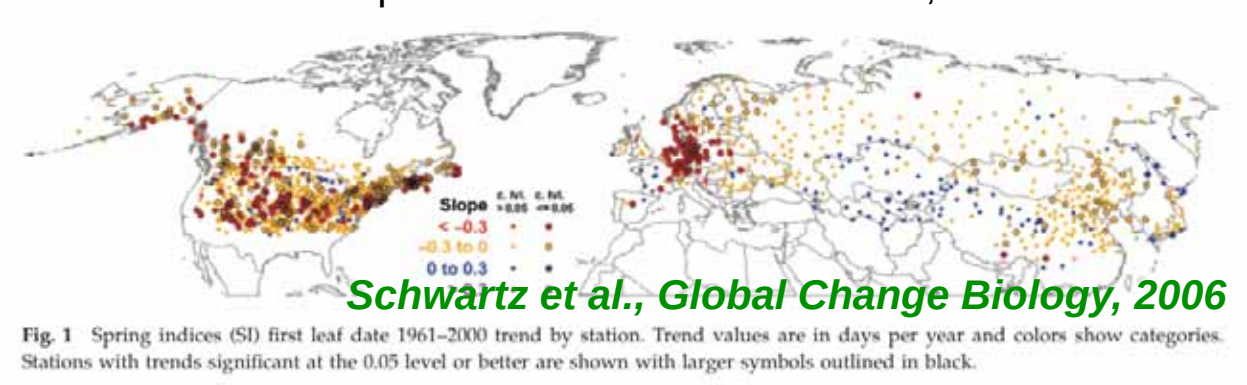
Other recent trends:

--> Earlier greenup dates

Northern Hemisphere trends in first-leaf dates, 1961-2000



Schwartz et al., Global Change Biology, 2006

Fig. 1 Spring indices (SI) first leaf date 1961–2000 trend by station. Trend values are in days per year and colors show categories. Stations with trends significant at the 0.05 level or better are shown with larger symbols outlined in black.

Note:

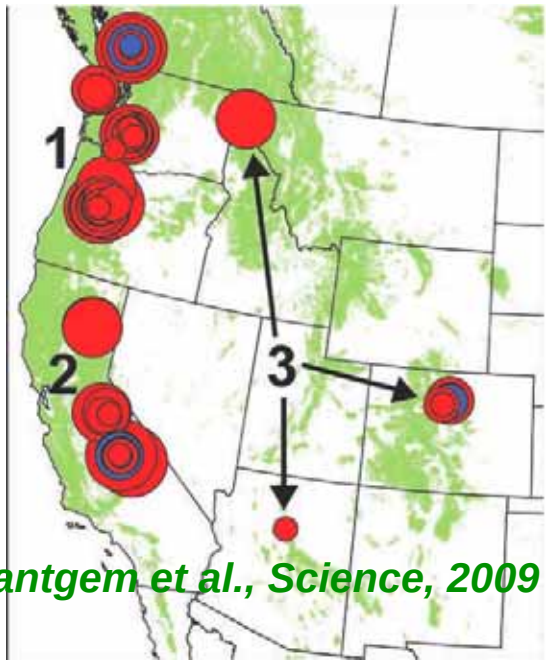
USA npn National Phenology Network

is now working to fill in (& restart) extensive phenologic monitoring in the US

Other recent trends:

The warming has doubled background tree mortality.

→ Increasing tree mortality rates



van Mantgem et al., Science, 2009

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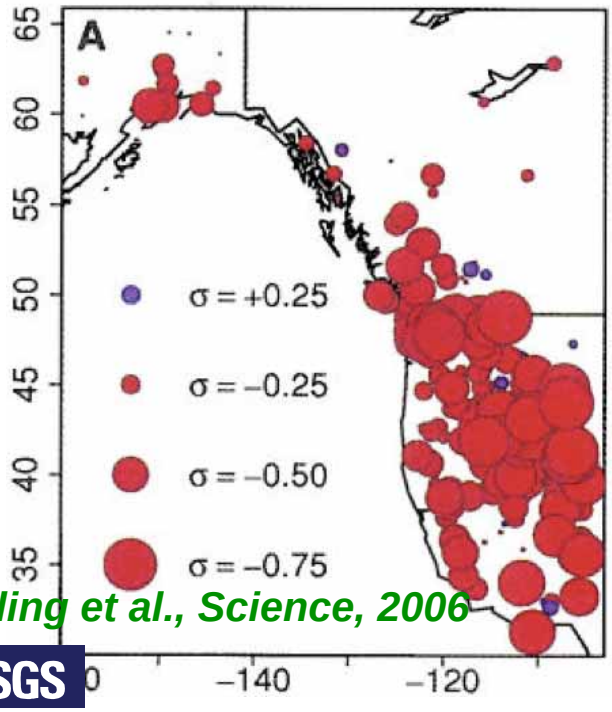
Other recent trends:

Warming/drying has increased forest wildfire risks.

→ Linked wildfire increases & warming



Westerling et al., Science, 2006

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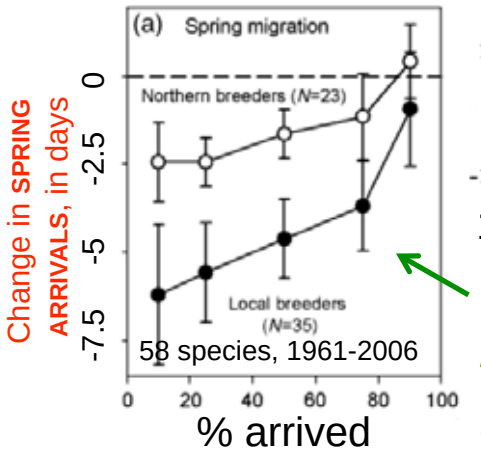
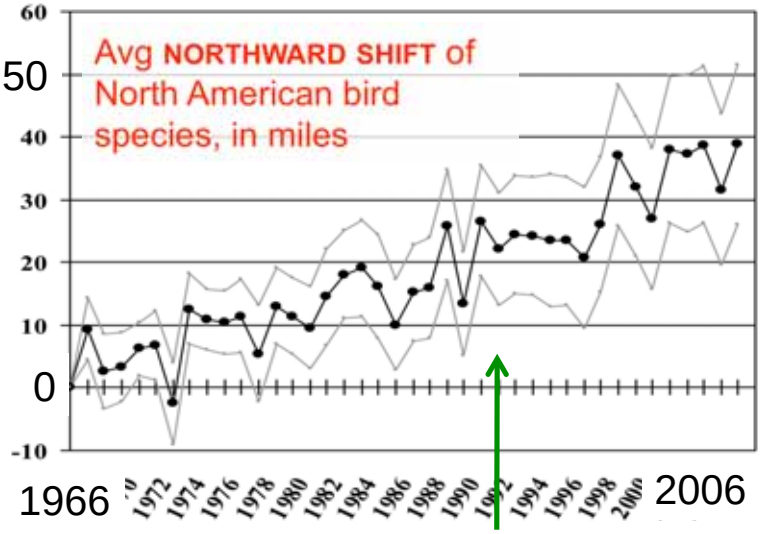
Birds & other species found farther north & earlier.

→ Latitudes & timing of species observations



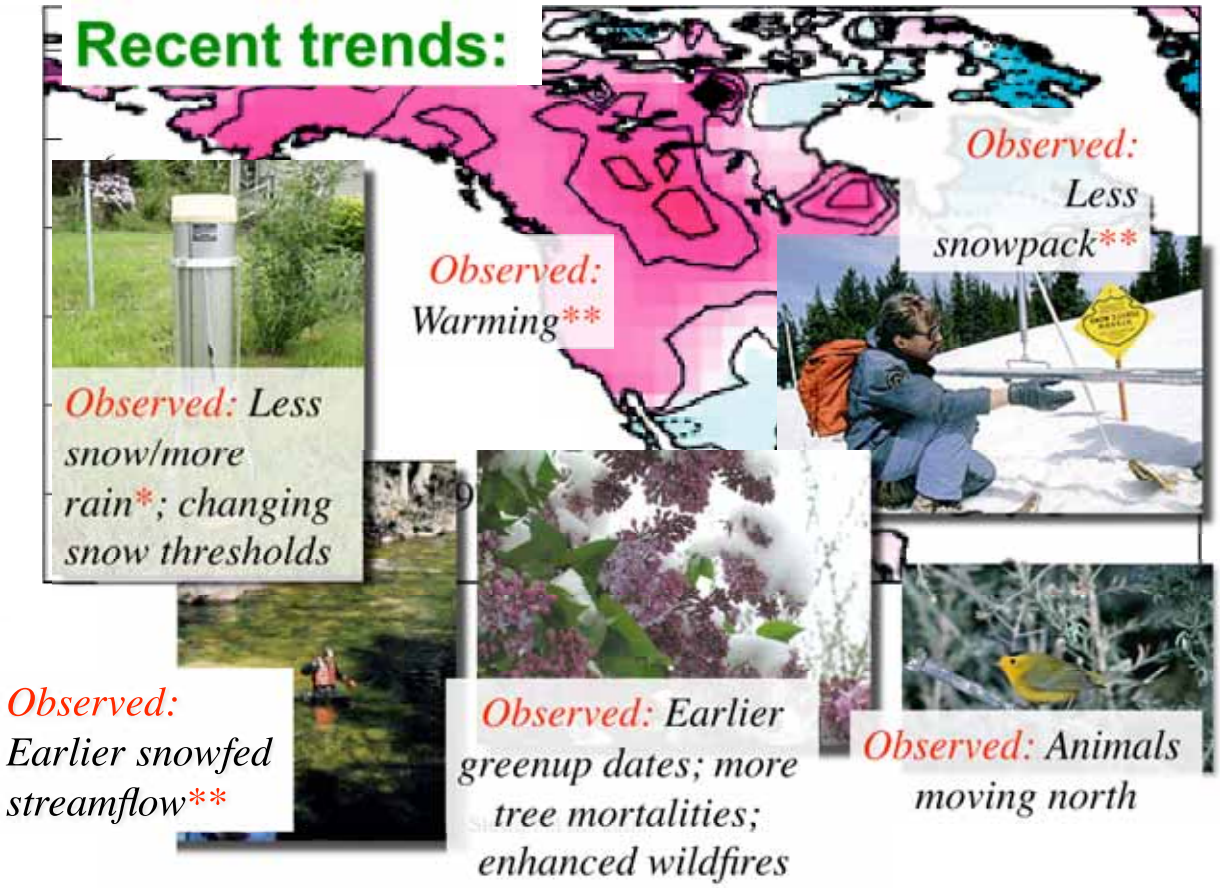
van Buskirk et al, GCB, 2008

(at one preserve in PA)



Niven & Butcher, 2009

Based on regular counts of 305 Audubon Christmas Bird-Count Species across North America


Recent trends:
Observed: Less snow/more rain*; changing snow thresholds
Observed: Warming**
Observed: Less snowpack**
Observed: Earlier greenup dates; more tree mortalities; enhanced wildfires
Observed: Animals moving north
Observed: Earlier snowfed streamflow**

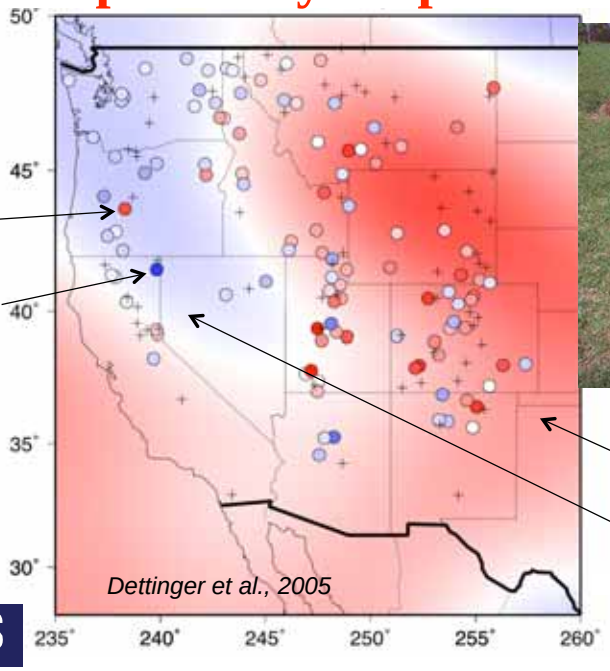
Other recent trends: This warming has already driven measurable hydrologic changes.

→Station temperature at which snow is reported by coop stns is changing

Symbols:

Warmer allowed with snow recently

Cooler required for snow recently



Shading:

500 mb warming > nr surface

500 mb warming < nr surface

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More-recent trends:

The western states have been warming in recent decades, and has continued extreme warmth in past decade.